Enclosure 1 – Regulatory Agencies' Interpretation of Destructive Testing Data

Based on a technical review of the destructive testing data, the Regulatory agencies recommend further evaluation and improvements to the TIRM process. This review is the basis for the disapproval of some of the Navy's interpretations. Given the concerns described in section one (below) over the lack of NDE correlation and corrosion rates, the Regulatory Agencies suggest that the Navy proceed with the following in evaluating current TIRM procedures and come prepared to discuss these and other actions to improve TIRM at the next scoping meeting with the Regulatory Agencies.

ADDITIONAL EVALUATION AND ASSOCIATED IMPACTS ON TIRM

a. Evaluate technology and develop processes to improve the Navy's NDE procedures. This new process should then be assessed for its effectiveness, which may be done with another destructive test.
b. Conduct additional analyses on the condition of the concrete structure and imbedded reinforcing steel.
c. Evaluate potential causes for corrosion and possible actions to reduce corrosion rates, if possible.
d. Immediately reevaluate the repair threshold and associated factor of safety to account for inaccuracies in NDE, corrosion rates, and possible delays in repair cycles. The Regulatory Agencies have noted that the CIR cycle of 20 years has slipped. Based on our calculations, the current CIR is averaging 30 years, with the longest duration being 59 years for Tank 18. We also note that while the next set of inspections are currently scheduled within 20 years, the schedule has already been pushed back from the time the TIRM report that was published in 2017.

The following describes in more detail the basis for the agencies' recommended actions:

1. INTERPRETATION OF COUPON RESULTS

Coupon 1 – False Positive

According to nondestructive examination ("NDE") data provided to the Regulatory Agencies, the site for Coupon 1 was initially indicated as needing a repair since phased array ultrasonic testing (PAUT) indicated a minimum remaining wall thickness of 0.112 inch. However, the laboratory analysis performed after the destructive testing indicated the remaining wall thickness was actually 0.208 inch and therefore a repair was not actually needed. The Regulatory Agencies regard this coupon as a false positive, meaning that a repair action was assigned, but a repair was not actually needed. The *Destructive Testing*

Results Report ("Results Report") states on p. 44 that a repair was specified, but the discussion on p. 61, seems to ignore the laboratory analysis and state that the need for repair was confirmed.

Although the Regulatory Agencies have greater concern with of false negatives, the presence of a false positive is still important. The Summary and Recommendations section of Results Report also seems to misinterpret the accuracy of the NDE for this coupon.

<u>Coupon 3- False Negative</u>

The initial screening of Coupon 3 with low frequency electromagnetic testing (LFET) indicated a thickness of only 0.033". The prove up with PAUT over the region, however, indicated no metal loss, but instead identified non-actionable lamination (p. 46). Based on the NDE, Coupon 3 was not recommended for repair (p.46): "Prove-up thickness (PAUT): No indication noted, so no repair recommended." The destructive testing determined that the minimum remaining wall thickness was 0.132 inch, indicating that repair should have been specified. The Results Report claims that a nearby area was indicated for repair and that for this reason, the site of Coupon 3 have been selected for a repair. The Regulatory Agencies are unable to verify that this would be the case and cannot corroborate that a patch plate finding the first piece of suitable metal would cover the site for Coupon 3. Both the drawing that the Navy provided, and the PAUT indicate that no repair would have been conducted. It is difficult to reconcile the basis for stating that a repair would be found at Coupon 3 when comparing what occurred at Coupon 8, for example. At Coupon 8, LFET indicated the need for a repair, but PAUT suggested that no repair was needed. In the Coupon 8 instance, a repair was not pursued, and the destructive testing corroborated that no repair was needed. Regarding Coupon 3, LFET identified a thickness of 0.033", but the technician could not find the defect using PAUT in the region (or had not proved up the region); hence, no action was recommended. The destructive testing, however, identified a pit with remaining thickness of 0.132" within Coupon 3, which is actionable. Hence, this should be a false negative.

<u>Coupon 6- False Negative</u>

A pit of concern was found through laboratory analysis at Coupon 6. This pit was deep, but of small volume. The Results Report claiming that this miss was caused by an instrumentation miss and not a technician error. The Results Report does not provide sufficient information to allow the Regulatory Agencies to validate the cause of this error. The Regulatory Agencies were assured that all areas of metal thickness below 200 mils would have been recorded during a first pass low frequency electromagnetic scan. The Regulatory Agencies also note that at 0.158 inches that this site should have been repaired. Page 61 of the Results Report also states that a repair was not needed which is not consistent with the repair criteria.

<u>Coupon 7- False Positive</u>

The Regulatory Agencies regard this coupon as a potential false positive, meaning that a repair action was assigned, but a repair was not actually needed. The *Destructive Testing Results Report* ("Results Report") states on p. 52, *"The LFET minimum screening thickness was 0.157 inch. The prove-up thickness was 0.135 inch. Therefore, a repair was specified in* *this area. Destructive testing found pitting and a minimum wall thickness of 0.164 inch. The remaining wall thickness was within the 20-mil range for pitting but thicker than expected for the prove-up testing (164 mils vs. 135mils)."* The actual vs NDE PAUT measurement exceeded the +/- 5% lab measured goal.

As previously stated, the Regulatory Agencies have greater concern with of false negatives, the presence of a false positive is still important. Both highlight the current inaccuracy of the NDE process.

2. DEFICIENCIES IN DATA COLLECTED / DEVIATIONS FROM WORKPLAN

The Navy's laboratory analysis did not or was not able to identify the thinnest portions of each plate which made a good portion of this destructive testing exercise and analysis incomplete. The thinnest portion was not found due to insufficient coupon cleaning and failure to complete profilometry of the entirety of each coupon.

The Regulatory Agencies disagree with Navy's statement on page 61 of the Report. *"The Navy holds that the analysis of coupons in this study is an effective means of validating nondestructive examination findings. ...Every coupon area at which the contractor did not recommend repair (Coupons 6, 8, 10, and A2) was found through destructive testing ("DT") and through additional analysis not to require repair after all. Every coupon area at which the contractor did recommend repair (Coupons 1, 2, 5, 7, 9, and A1), as well as the one coupon area near which the contractor found an indication of excessive backside corrosion (Indication B near Coupon 3) that warranted repair, was indeed found by DT to be thin enough to require repair. Therefore, the NDE results are validated, both by DT and thorough, case- by- case analysis."*

3. UNCERTAINTY REGARDING NON-DESTRUCTIVE EXAMINATION (NDE) ACCURACY

The Regulatory Agencies believe that there lacks sufficient correlation between NDE and the laboratory measurements, therefore further evaluation of NDE procedures should be pursued.

a. The Destructive Plan, section 3.1.1 *Screening Criteria* on pages 3-4, outlines the current TIRM procedures to be validated by the destructive test. For example, the expected accuracy for the NDE measurements is as follows:
   - "Backside Pitting. Prove-up measurement (pit depth) within 20 mils of actual laboratory results.
   - Wall Thinning. Prove-up measurements within 5% of actual laboratory results."

   In the Results Report, five of the ten coupons had Phased Array Ultrasonic Testing (PAUT) or prove-up measurements provided. Only two out of five (40%) coupons had PAUT-measured pit depths within the 20 mils and/or +/- 5% of the laboratory-measured value. Table 1 below shows the difference between PAUT-measured values and actual laboratory-measured pit depths.

Table 1. Phased Array Ultrasonic Testing (PAUT) Comparison							
Coupon #	EEI (PAUT) NDE Remaining Thickness (mil)	Thinnest Laboratory Measured Value (mil)	5% of Laboratory Measured Value (mil)	-5% (mil)	+5% (mil)	Test Tolerance (In/Out)	Difference between PAUT and Laboratory Measured Values(mil)
1	112	207.9	10.4	197.5	218.3	Out	-95.9
2	150	152.4	7.6	144.8	160.0	In	-2.4
7	135	163.8	8.2	155.6	172.0	Out	-28.8
8	200	205.9	10.3	195.6	216.2	In	-5.9
10	200	241.7	12.1	229.6	253.8	Out	-41.7

b. Based on laboratory measurements, four out of ten coupons reversed their repair status as intended based on NDE measurements. Coupons 1 and 7 changed from a Fix to No Fix status ("False Positive"); whereas, Coupons 3 and 6 changed from a No Fix to Fix status ("False Negative"), which indicates a 40% error rate. In general, false negatives are of greater concern because the unidentified pit or corrosion areas will remain unrepaired and depending on its size, could potentially develop into a through-hole leak prior to the next Clean, Inspect, and Repair ("CIR") cycle. Coupon 6 is a concern since the Low Frequency Electromagnetic Testing ("LFET") did not require further evaluation. While the actual pit was a few mils under the 160-mil repair threshold established for Tank 14 CIR, the fact that the LFET scan was not able to identify this pit did not allow for the PAUT, the Navy's identified "prove-up" process, to further evaluate the need for repairs.

c. The Navy contends that the false negative of Coupon 3 was a result of an incomplete NDE process and that the NDE process worked. However, based on the information provided, the Regulatory Agencies disagree with this assertion.

   i. First, the report states, "During the PAUT prove-up, the 33-mil thickness was identified not to be metal loss but instead was a non-actionable lamination. Therefore, a repair was not initially specified in this area. Backside corrosion was not expected." Figure 4-5 description mentions that "PAUT prove-up determined no repair."

   ii. Second, the report further notes that the PAUT technician could not find the 33-mil measurement in Indication A, which is consistent that a repair was not identified in this area and only in Indication B.

   iii. Third, the report states that the repair for Indication B was incorrectly inputted as the repair for Indication A (noted as repair of 15 inches wide and 8 inches high, at x= 7 inches and y=5 inches).

We agree that the repair appears intended for Indication B based on the handwriting on the tank wall and on the listed coordinates. With this understanding, the intended repair would not have covered the corrosion found behind Coupon 3. Note that the Computed Tomography ("CT") scan version (Figure 4-6 on page 47) of the coupon should be rotated 90 degrees clockwise and flipped 180 degrees on horizontal center axis to bring the drill hole of the Coupon 3 in alignment with Figure 8 on page 31 of Results Report Appendix A and Figure 4-7 on page 48 of the Results Report. The proper orientation of the CT scan photo indicates that the corrosion area requiring repair is further away (left-hand side of Coupon 3) from Indication B as depicted on page 48. Therefore, the report's statement, *"Laboratory results from Coupon 3 showed an area of remaining thickness of 131 mils, which is actionable. This thickness is within the layout area of Indication B."* is incorrect.

d. The Regulatory Agencies are concerned that the thinnest metal location for Coupons 2, 7, and A1 may not have been located, further questioning the Navy's conclusions on NDE accuracy. As specified in The Destructive Plan, section 4.2e., the Results Report does not contain three-dimensional ("3D") profilometry data after proper cleaning of the coupon. 3D profilometry data would have provided a more detailed surface characterization of the exterior and interior surfaces of the steel coupon. Further discussion on this issue is provided in enclosure, Hihara Corrosion Consulting (HCC), LLC, *"Corrosion Report on Red Hill Bulk Fuel Storage Facility" ("HCC Corrosion Report")*, February 5, 2020.

4. POTENTIAL FOR INCREASING CORROSION RATES

The Regulatory Agencies believe the Navy is underestimating corrosion rates for Tank 14 and should reassess corrosion rates as used in calculating repair thresholds under TIRM. In addition, the potential cause for increasing corrosion rates creates concern for potential corrosion of imbedded steel in the concrete.

a. In calculating corrosion rate for Tank 14, the Navy used the thinnest metal thickness identified by the laboratory in Coupon 3, 131.5 mils, subtracted from the initial metal thickness of 250 mils and divided by the number of years that tank was in service. The Regulatory Agencies have multiple concerns in the way this corrosion rate was calculated.
    i. Although Coupon A2 had the thinnest laboratory-measured thickness at 122.4 mil instead of 131.5 mil for Coupon 3, this thinnest measurement is only representative of the 10 coupons. These coupons did not represent the most corroded areas of Tank 14, so a thinner wall thickness may exist.
    ii. Navy should look at their past tank repair records and use the first reported tank through-hole to establish a worst-case corrosion rate. As an example, *Red Hill Facility Tank Inspection, Repair, and Maintenance Report (AOC/SOW), Section 2.2 of 11 October 2016*, page 18-1, mentioned tank through-hole found during Tank 16 repair in May 2006 with a corrosion

rate of 3.72 mil/yr. While we recognize that corrosion rates among tanks may not be consistent as explained in HCC Corrosion Report, a worst-case corrosion rate should be established by Navy in assessing repair thresholds that would be most protective of the environment.

iii. The Navy assumed that corrosion would occur at a linear rate over the life of the tank. Environmental and chemical conditions may increase corrosion and need to be taken into consideration in estimating corrosion rates. The basis for consideration is further discussed in the paragraphs below.

b. Results Report, page 61, states, "On-site testing and laboratory testing of concrete powder samples indicated that the concrete behind the steel tank liner is alkaline and in sound condition. Alkaline concrete is necessary to avoid corrosion." The Regulatory Agencies believe that there is greater concern for corrosion and the potential for increasing corrosion than the Results Report implies. The enclosed HCC Corrosion Report (Enclosure 2) provides detailed analysis of the current state of corrosion as related to the ten coupons removed from Tank 14. A summary is presented below.

   i. Tables 15 and 16 of the Results Report Appendix A show measured pH is less than (<) 11 for concrete samples behind seven out of ten coupons, whereas pH for fresh concrete is around 13 or 14. When pH < 11, the concrete's ability to protect steel from corrosion decreases and corrosion rates start to increase and accelerates as the pH levels drops.

   ii. Table 3-11 of the Results Report lists the structure-to-electrolyte corrosion potential and shows that only one of ten coupons have a low probability for corrosion, while four of the ten coupons indicate active corrosion. When compared with remaining plate thickness, a strong correlation between remaining plate thickness and corrosion potentials was observed. The remaining plate thickness decreased as the corrosion potential decreased, indicating various degrees of active corrosion.

   iii. Corrosion rates of steel can increase by 1) decreasing pH of concrete caused by carbonation (the production of calcium carbonate when carbonic acid from carbon dioxide reacts with calcium hydroxide) and 2) by elevated concentration of chloride ions. Corrosion product samples from seven of ten coupons had concentrations of chloride ions >0.3 wt %.

c. Understanding the potential causes for corrosion (i.e., high carbonation, presence of chlorides), may also help recognize the potential for increasing corrosion rates. One theory is rainfall infiltration.

   i. Energy dispersive X-ray analyses (Tables 6, 7, 8, 9, 10, 12, and 13) in Appendix A of the Results Report indicate the presence of chlorides in the corrosion products of the steel plates. The levels of chlorides in the corrosion products were significantly higher than those in the concrete (Tables 15 and 16) suggesting that the source of chlorides may be elsewhere, such as rainwater percolating through the soils and concrete above the tanks and then selected regions of the structure. This could also explain the relatively high levels of nitrite and nitrate in the concrete (Tables 15 and 16) and the carbonation of the concrete. Water percolating through soils can pick up nitrite and nitrate from decaying vegetation and animal residue. Dissolved carbon dioxide is also a byproduct of decaying organic matter.

ii. The Results Report described voids between the concrete and steel liner in nine of ten coupon areas, ranging from 1/16-inch to ½-inch, providing the possibility of rainfall to more readily move along the tank liner. As mentioned in the *Historic American Engineering Record, no. HI-123, 2015, National Park Service, U.S. Department of the Interior,* report, the "removal of the tell-tales eliminated a way to drain off any rainwater that percolates down through the lava rock and finds its way into the space between the back side of the steel shell plates and the inner side of the concrete wall. The standing water could cause accelerated corrosion of the back side of the steel shell plate."